Geoservices for Aeronautical Navigation

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Abstract: Aeronautical charts underlie the representation of aeronautic geographic information that supports pilots in flight. Nevertheless, the charts become complex due to the high density of data and the different kinds of charts that support each phase of flight. These features make difficult using them on board. After conducting a study, with civil Spaniard pilots, that aims to understand and to evaluate their needs related to Geographic Information, it is proposed a solution to implement a platform based on geographic information standards (OGC, ISO) and supported by a distributed Web architecture. This platform facilitates the use, retrieval, updating of information and its exchange among different institutions through private and public users. As a first element to ensure interoperability of information, we suggest an aeronautical metadata profile that sets guidelines and elements for its description. The metadata profile meets the standards set by ICAO, Eurocontrol and ISO. The platform offers three levels of access to data through different types of devices and user profiles. Thus, aeronautical institutions could edit data while pilot is on board accessing digital aeronautical charts through a laptop or Table PC. This paper suggests an alternative and reliable way for distributing aeronautical geoinformation, focusing on specific functions or displaying and querying.

Keywords: aeronautical services, aeronautical navigation, aeronautical data server, aeronautical metadata profile, OGC.

1. INTRODUCTION

In order that air navigation can be safe, it is essential to have reliable and updated information. In this way, the aeronautical charts are an essential tool for navigation. They are used both in the planning stage and in the steering and control. As support for providing manageable, robust and coordinated aeronautical information; the aeronautical cartography is part of information services that government agencies provide to the users of the standard navigation system. But this information is scattered and is stored in different formats or represented in different media: paper, optical media, stored on discs, etc.

These problems have already been studied in other contexts. Due to this, some technologies, methodologies and tools are available to perform multiple operations (query, download, updating, editing, etc.) using geographic data of different nature. These are general-purpose technologies for the access, distribution and visualization of geographic information. These procedures, based on ISO standards and OGC specifications, allow its implementation in different technological platforms which have been developed by several years and have demonstrated their effectiveness. Therefore, it is possible to conclude that the development of Geographic Information Technologies –GIT– and its application in the aeronautical context makes possible the publication, discovery and access to updated aeronautical cartographic data, so quickly and in a reliable way through the network.

After conducting a study with civil Spaniard pilots in which the aim was to understand and to evaluate their needs related to Geographic Information; it has been pointed some processes associated with the use and provision of aeronautical cartographic information that can be improved significantly. The study highlights the need to supply aeronautical data from a universal, certified and updated data infrastructure.

In response to these shortcomings, it's proposed the development of an application which serves geoservices and data. It can be used as a tool for accessing and querying the different kinds of aeronautical charts in order to permit the use and operation of aeronautical data services through standardized tools. One of the advantages of the proposed service is that it would address the excessive growth of the data that must be represented on the charts due to the increase of air routes. In this way, the flight crews will be supplied with personalized information according to the profile of the aircraft, flight phase, and operational needs on the ground. Thus, the pilots (user system) will find centralized in a single system all the information that they require for each phase of the flight. Also, they will have tools that allow them to join and to link the information used in the different phases of the flight.

For the prototype, the Aeronautical Information Division of Aena (National Airports and Air Navigation from Spain) facilitated a sample of aeronautical charts and data that were taken from the Aeronautical Information Service. This paper also describes some elements that must be taken into account in order to represent aeronautical charts online through tools that were originally designed for representing conventional cartography. To develop the prototype, some open source technologies has been selected and used because of the flexibility and facility of customization. MapServer, Apache and PHP MapScript are the technologies in which the prototype is based on.

This paper is divided as follows; part two presents a description of aeronautical geographic information and electronic display systems. Part three describes the poll we have taken in order to identify restrictions in the communication process of aeronautical geographic information. Part four relies on a technical description about the technology this proposal is supported on. Parts five and six describe the proposal. Finally, conclusions are presented, and further steps to strengthen the platform implementing other geoservices are discussed.

2. AERONAUTICAL GEOGRAPHIC INFORMATION

The use of geographic information has suffered a long evolution in the aeronautical issues. At first, pilots were able to use rudimentary cartography for flying by geographic reference. This methodology evolved quickly and some navigation systems were developed in order to help and guide pilots. This section shows the evolution of aeronautical geographic information and the way new systems aid the navigation process.

2.1 Use and evolution of geographic information

In the early aviation, pilots had strong difficulties to know accurately the area they were flying. The aeronautical cartography was so poor and it couldn't help pilots to reach at minimal orientation.

Aeronautical charts were not edited and published until the 20's of the last century [19]. Instead of it, pilots were used to using conventional cartography of roads which they could use to find coastal, rivers and roads in relation to the surrounding reality [7]. The pioneers of aviation flew using the Michelin Guide the whole time. However, it was not possible to use always the maps. Some trivial issues, such as the arrival of the night or the challenge of identifying roads airports and points of reference when suddenly the ground was hidden by clouds, gave rise to loss of orientation, and sometimes tragic accidents.

Given the difficulties in developing visual systems that can recognize the ground at night across clouds, it was designed a new no visual system through which the pilot could receive a radio signal to be oriented in space: it was the beginning of what is known as radio navigation [25]. The Second World War and the hard post-war were important milestones for the great development of this field. It was because of the radio helps (NDB, VOR/DME and subsequently the ILS) that commercial air companies could fly with a high security level, something unexpected until then.

The aeronautical charts used for radio navigation implied a high detailed visual abstraction of reality. Thus, representations of geographic phenomena were diminished, and non-tangible elements related to the structure of the airspace and standard navigation procedures appeared profusely: airways, routes, distances, altitude limits, frequencies, etc.

2.2 Electronic display systems

Later on in the seventies, the civil aviation industry was launched in the race for the automation of piloting systems. But it was not until the early 80's when the geoinformation that pilots used on board suffered a big revolution. Thus, the first CRT displays appear in the cockpit [8] and with them the ability to display at all time the actual path of the airplane using a schematic drawing with light strokes. For pilots, who were always fearing the possibility of getting lost outside the planned route, have this horizontal situation indicator represented the *summum bonum* of their spatial orientation.

Up to now, navigation displays have been supplemented by traditional aeronautical charts without problem. But nowadays, new technologies for computation, conceptualization, and communication are making significant changes and advances. At first, we must consider the technological support; the use of TFT displays in the cockpits ensures adequate support for digital mapping and therefore a really good chance of changing the way to show traditional aeronautical charts [33]. The second one is the international agreement for implementing and using a conceptual model for the exchange of aeronautical information that take into account both the operating systems and concepts such as data exchange and interoperability [3]. This will result in the future on a single coordinated and certified source of aeronautical geoinformation which will be available aboard any aircraft.

3. USE OF AERONAUTICAL INFORMATION

Through a poll, we have identified some shortcomings that will be minimized by applying concepts such as geoservices and map servers. This section describes the poll, its goals, the methodology and implementation, and finally some conclusions which highlight the shortcomings that will be covered through our proposal.

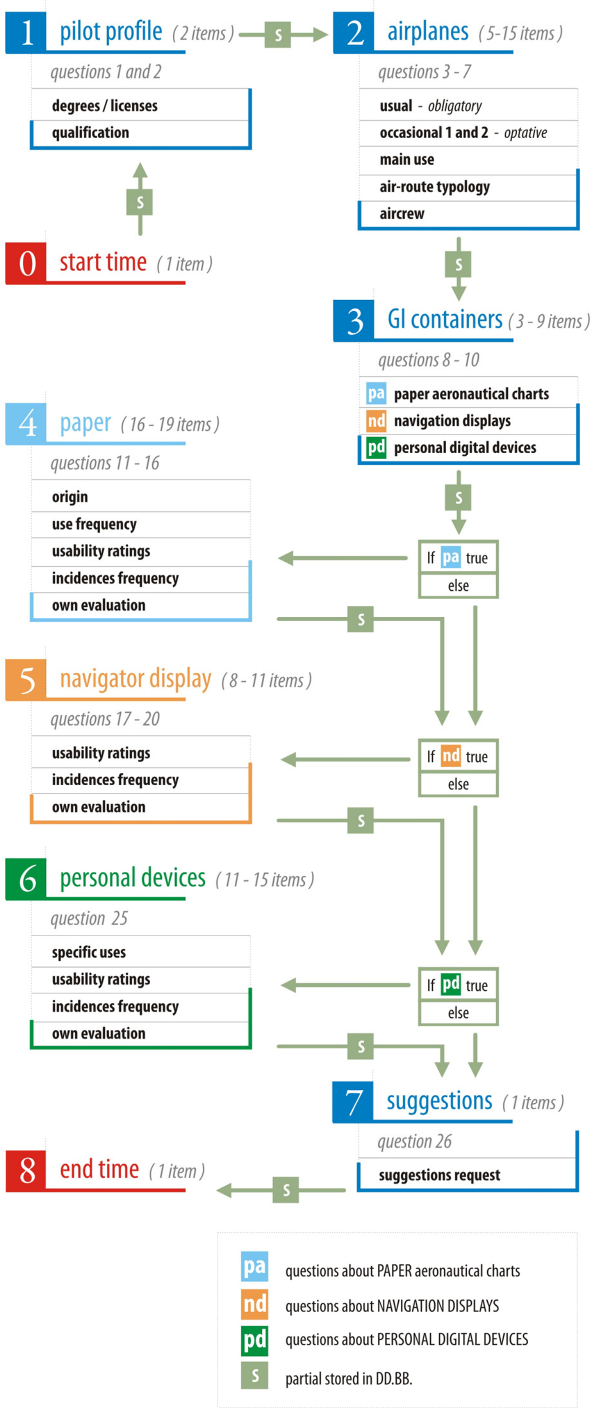

Fig. 1 Scheme and flow of the poll.

Through a previous study conducted by our group, it appeared that the actual in-flight use of aeronautical geographic information can be systematized keeping in mind some different aspects namely the aircraft type, the characteristics of the navigation equipment on board, typology and specific phase of the flight, and so on. There are also some important external constraints such as operational restrictions, weather, and orographic characteristics.

Afterwards, some crew-opinion poll was conducted so as to know their thought about this fact. Among the lessons learned in this activity should be noted that each crew member has different preferences on how to use devices that provide

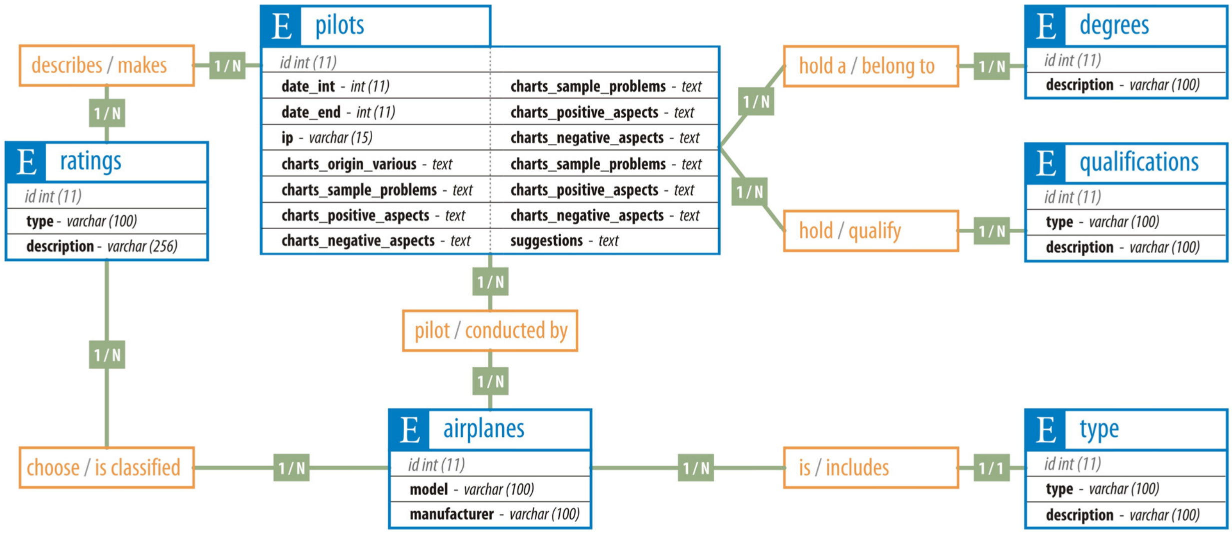

Fig. 2 Entity-Relationship model

geographic and aeronautical information (IG). This behavior depends critically on the different operational circumstances; the intrinsic capabilities of each media-format (analog/digital); as well as personal tendencies of each user. This last fact is particularly interesting to investigate, but the study must be based on variables and measurements that will comprise subjectivity.

3.1 Goals and methodology

Once we have finished the initial analysis, it was proposed to focus the investigation on the effective use of aeronautical geographic information on board. Thus, we could quantitatively identify different variables such as the use of different technological elements, regulated procedures involved and particular needs and preferences. For the purpose, the crews of commercial flights were considered as the primary source of information, although not ruled out other non-commercial type.

To solve similar problems, it is usual to opt for the systematic collection of data from a target group (in this case flight crew) through the use of personal interviews or similar instruments to obtain data. In this case, it was established as a research tool in order to collect information a single sample poll based on a normalized quiz. The idea was to facilitate the quantification and universality of information, allowing also multiple comparisons of the information collected.

For collecting data, the poll was implemented online with access restrictions [29]. The pilots need a user and password in order to fill out the forms. The data are stored in a data base designed to analyze and explode data using data-mining strategies. Thus, we can ensure to analyze the data in the right way; find out not evident characteristics and converting data into useful information. Fig. 2 shows the E-R model of the data base.

Other important characteristic of the implementation is that forms are programmed implementing automatic validations, restrictions and contextual help. This way, pilots can avoid mistakes and possible disorientations when they are filling out the poll. For assuring confidentiality, the poll is totally blind.

Due to the fact that the poll is always available, we can extract partial and new conclusions any time. This is so useful because we can analyze trends according to profile and context. Depending on the pilots' profile, the poll can be adapted and the flow of information change according to what the respondent answers. Fig. 1 shows the flow of the poll and the way how pilots can interact with it.

3.2 Design and development

Aboard an aircraft, the provision of geographic information focuses on specific tangible containers. This also implies that a process of communication between the pilot and the device, the system or the object is establishing. This last process is particularly interesting in our study.

Three different containers were defined as follows: (i) aeronautical charts on paper, (ii) navigation displays (ND) of the aircraft's control panels, and (iii) personal devices for querying digital mapping, programs and flight manuals. In any event the ground control was obviated as another possible source of geographic information because pilots neither use nor manipulate this kind of information.

Brought up the overall goal and containers, next step was developing of the forms. The flow applied to the forms is divided into two phases. The first section identifies a basic profile of the pilot, the different aircrafts that he steers (allowing up to 3) as well as containers of geoinformation he is used to use. The second phase asks about different characteristics of the containers namely requirements, usability, frequency of use, etc. Depending on the pilot has selected in previous section, he will describe one, two or three containers using a different block for each one. The technique implemented for personalizing the flow optimizes the time that the respondent should expend to completing it. The system omits a priori variables that are irrelevant for each particular respondent depending on its profile.

The form is compound by 26 questions and it is possible to store between 51 and 73 different variables for each respondent. In order to facilitate the process the poll was divided into thematic blocks. The poll was validated by pilots and some trials were made before publish it [29].

3.3 Analysis and results

In practice, a poll gets single data in order to obtain aggregate data during the analysis. The aim of the evaluation and analysis can be supported by twice levels: on the one hand description and on the other hand discovering and comparison of relationships.

As already discussed, the programming not only has achieved the automation of data collection but also has tried to facilitate data extraction and analysis. So that, we have established SQL queries on two levels: the first one aims to extract specific data (sum and calculation of percentages with regard to total-respondents or specific subgroups). The second one, more complex, addresses the particular comparison of relationships that are of interest once we have analyzed the previous queries. While we wrote this paper, we had not yet closed the collection of polls. However, partial results let to highlight certain points of interest, and discover various problems related.

In most of the multiple choice questions related to aeronautical charts on paper; pilots identifies as a huge problem the excessive density of information presented on the charts they handle. This fact makes difficult both extracting information quickly (> 80%) and the interpretation of the data (>70%). However, it doesn´t appear to be overly problematic the way that graphic semiology is determined (<30%) because pilots are familiar with their formal symbolism. They were asking about the personal assessment of this media. In most cases, they appraise the fact that charts offer a reliable way to get information. The drawbacks are the size, the lack of enough physical space in the cockpit for handling and storaging this information. In fact, they refer the importance of maintaining a strict order of storage in the cockpit to get charts speedily.

Through open questions pilots are in disagreement with the high density of information showed in a little sheet of paper (charts). Moreover, they express their displeasure when reading these charts due to the tiny size of the characters in the charts and harder when they try to read it in difficult atmospheric conditions such turbulences.

With regard to whether these problems can lead to incidents that could compromise the navigation safety, the results did not seem worrisome. Neither the potential problems of use nor interpretation of charts have generated a remarkable impact on instrumental flights (IFR). However, there are a percentage of pilots (15%) that recognize problems induced by the wrong use or interpretation of the charts on visual flights (VFR).

Initial results related to the analysis of the use of navigation displays indicate that these electronic devices significantly improve the problems of interpretation and speed in the query, but still face the problem of density of aeronautical geoinformation. Thus, while the level of satisfaction with display modes reach higher values (>75%), the percentage of pilots that consider inappropriate the density of information provided on screen (although not as high as in the charts) are still very significant (>65%). It is also striking that pilots are not satisfied with these devices and the way it represents the orographic details. Most of them (>80%) consider it doesn´t provide enough information for a safer navigation at low altitude.

Asking for pros and cons about navigation displays, pilots stress above all that moving-maps allow them to know at all the time where they are (situational awareness), which implies a sense of control and security. Other aspects as the fast and easy interpretation of the information, data integration and a possible selection of information are also highly valued. It is precisely this last feature the one that does not seem to solve the saturation of information on the display. It also refers to the quality and resolution of the screens as factors to improve.

The partial results also reflect that neither the difficulties of interpretation nor technical anomalies occurring along the experience of the crews have come to generate a remarkable frequency of incidents.

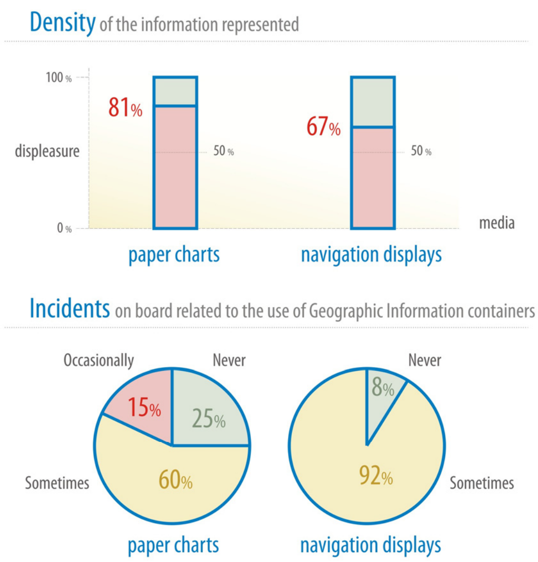

Fig. 3 Some problems and incidents related to GI

Regarding the use of personal devices for querying digital charts in flight, contrary to expectations, is certainly residual (<5%). But there is not enough data to be concluded about this topic. Anyway, design and architecture of our server keep in mind this kind of devices.

3.4 Conclusions of the poll

Although fully retains its properties of reliability and security for supplying information, the paper charts looks obsolete and overwhelmed with the current needs of providing operational information to flight crews. Moreover, the massive introduction of visual displays in the pilot's seat (portable or integrated) allows a very suitable environment for the provision of electronic charts, but this element by itself does not solve the problems discovered.

This is precisely the topic we are dealing with on this paper. New methodologies and software applications developed to explode this new opportunity to show aeronautic geographic information on board and provide a solution which permits cartography get across aeronautical geographic information, attributes and situation, in an effective and functional way. This will help pilots to use and analyse better and faster the information they are watching while flying.

On sight of these preliminary but concrete results, a good way to improve these processes is the personalization of the information flow and the way how pilots access and query aeronautical geographic information. Aeronautical charts by themselves should be capable of representing digital information in a personalized way.

4. GEOSERVICES

Once we have identified these shortcomings we propose a solution using geoservices. As we mentioned before, there are many different technologies we can support on. This section shows in brief a description of what geoservices are and the different technologies in which the server application relies on.

The proliferation of spatial data on the Internet is beginning to allow a much larger audience to share and to access the rich databases that are currently maintained by private and governmental institutions, universities, local and regional governments, and others. These databases are mainly used by themselves, by geographic information system specialists and users, and by citizens also. This is due to the fact that the Spatial Data Infrastructures (SDI) technologies allow everybody to access this kind of information through the network. Nowadays, it is evident how this infrastructure offers benefits such as better coordination, more integrated thinking and planning, a richer learning environment and, a society that better uses and access the geographic information. As Dangermond asserted [2], "The demand for quick and easy access to accurate spatial data continues to rise as more organizations realize the value of using geographic information to solve their problems". Actually, do not only organizations but also people using geographic services every day.

When the SDI started, the focus were data and many years the efforts were centralized in this topic. Despite all of the on-line digital data now available and the vastly increased power of GIS, it is still common to spend 80% or more of a project's resources on searching, discovering, assessing, retrieving, and reformatting data [24][26]. So, there is enough information but not completely useable. That's why there was a turn from a data-centric to a service-centric perspective. This new perspective of geographic services (geoservices) is the one we will use to propose a new way for improving aeronautical navigation based on the geography network.

A geoservice is a tool that performs geoprocessing, visualizing, accessing and discovering functions such as geocoding, routing, rendering, filter encoding, measuring, describing, buffering or a gazetteer service (geographic dictionary) among others. These kinds of services are published using the standard geography network XML communication language so that all requests for like services are handled the same. These services can be used by developers and applications service providers (ASPs) for building new online solutions or just for using them.

The geoservices can add spatial functionality to many applications which were initially thought for different aims. In addition, they can be used in wired and wireless environments. Probably, this is one of the main characteristics which let to use this technology in the aeronautical environment. We must take into account that aircraft's communications must be wireless.

Initially, the whole processing tasks were executed at the server side due to the lack that wireless devices had in processor power and memory to perform geoprocessing by themselves. This way, hand devices were considered simple stations for showing information. But nowadays, these devices reach up to 800 MHz and 512 Mb of memory, enough to perform some basic processing tasks. Of course, this is independent of notebooks and table PCs, which look like to be the best option in order to show and query geographic aeronautical information on board; or at least complementary information.

But not only data and architecture are relevant elements for geoservices. The physical medium is also a very important topic. In this case, wireless communications are regulated by the family of IEEE 802 Standards [15] and the ones related to the authorized bandwidth for transponders (between 1030 MHz and 1090 MHz). For instance, IEEE 802.11 is a set of standards carrying out wireless local area network (WLAN) computer communication in the 2.4 and 5 GHz frequency bands (public bands). They are implemented by the IEEE LAN/MAN Standards Committee (IEEE 802) [11]. 802.11n standard [8] (still draft) must be highlighted because it will be approved before the year is out. Using this standard the transference data speed will be able to reach up to 600Mbs. So, this rate makes possible to transfer a huge amount of data and geoinformation so fast.

This is a valid scenario for not too long distances, up to 40 Km, and it requires high-power antennas in order to keep communication. In this way, the radio communication could be in most of the cases the best option (transponders).

In conclusion, we have comprehensive system elements to think about aeronautical geographic services. Very strong and well supported software technology, appropriated wireless devices and strong standards which let possible to transfer geographic and aeronautical data and geoinformation very fast.

4.1 Classification of geoservices

It must be taken into account that no new technology can emerge, and particularly no new information technology, without extensive standard-making activities. The geoservice technologies are regulated by the Open Geospatial Consortium (OGC) and by the ISO/TC 211. This proposal service is supported on a comprehensive set of recommendations and standards in which the ISO 19100 standard family is the main one.

The OGC has defined a taxonomy which lets classify geoservices in four main classes depending on its functionality: geocoding, accessing, rendering and geoprocessing. Besides a set of specifications which standardized the communication procedures between the clients (users) and serves (service providers). Table 1 classifies and describes shortly the services and specifications which could be useful for implementing aeronautical navigation geoservices.

Most of these standards and specifications are thought of a way for sharing services and geographic information. GIS geoinformation has evolved to support a network-based architecture. This architecture is collaborative and allows organizations to share and use geoinformation from many distributed sources at the same time. So, there is a distributed platform of accessing and processing geospatial data using distributed geographic information service components on the Internet. It relies on mobile client components that communicate directly with objects and data on multiple servers across the network. Of course, this client is an interoperable component which is based on international standards as described above.

This way, pilots could reach aeronautical geoinformation from multiple sources at the same time. For instance, each airport could configure local servers in order to show detailed, updated and customized information of landing strips and airfields. The pilots request the channel in order to access geoinformation and visualize it on board. They could also request a geocoding service that helps them to find faster and more secure the gate they are looking for. This is what we propose, a complete system where aeronautical geoinformation were integrated and can be accessed through standards using web geoservices. This information will not replace the actual information on board, it just try to advocate the current navigation systems.

4.2 Aeronautical geoservices

Internet geographic information services have become more important to the professionals, researches and public in general. This is precisely the group of people to whom we want to focus our proposal. Extending GI services to aeronautical world in order to explode the technology we have described until now and apply it for improving the way pilots and other professionals use aeronautical information.

Another underlying reason for the implementation of this technologies and Internet-based services is the need for communication. The real reason for distributed GI Services on the Internet is that communications are efficiently and effectively. As we said, quit good communications and data transfer of geographic information across wireless networks can be possible with enough quality and speed. This way, communications between servers and users (namely pilots) are reliable and secure.

First of all, we must think about data. What kind of data will be published on the server? Is there a model that represents these data? These questions must be kept in mind because depending on the nature of data, geoservices can be implemented in one way or another. In this case, data follow the Aeronautical Information Exchange Model (AIXM) [4] which is designed to enable the management and distribution of Aeronautical Information Services (AIS) data in digital format. Taking into account our proposal is intended to help the aeronautical community and information services to adopt these kind of methodology, it is imperative driving our data through this model. This way we guarantee that the server supports current and future aeronautical information system requirements.

With data, next step is to think about services. It is possible to classify geoservices into two general groups depending on its functions and the way how they process data: serving data services and processing data services. On the one hand, we have services for serving data as they are (considering that they can be rendered using different formats). This is especially common in services namely WFS (query functions) and WMS which are ready for serving geographic data to anyone who request it in order to represent it on digital media through web browsers. These services are very useful for sharing data with normal users or different institutions that can be interested in accessing aeronautical geoinformation. For instance, from now on the Japan Society for Aeronautical and Space Sciences could access aeronautical data from the Aeronautical Information Service from Spain if they decided connect to their servers. On the other hand, there are services which process information and solve a specific problem, this kind of geoservices such as WPS are very useful in order that pilots and users can have specific functions for visualization or ask explicit questions to the system. In this case, services use original data and geoinformation so as to deliver the result of the process. For instance, when users request information they can use any kind of mobile device (namely Table PC, hands-on devices, navigation displays an others) and system must know what kind of device makes the request and the way it should process data to be showed on the client-side.

In this sense, we propose three different schemes for our aeronautical data and geoservices server: (i) a private data server which will serve the whole aeronautical dataset of Aena which comprises an informatics system based on Oracle, ArcSDE and MapServer. (ii) A group of geoservices which will become accessible and query-able some specific aeronautical data layers such as VFR (Visual Flight Rules), RNAV (Area Navigation) and IAC (Instrument Approach Chart). (iii) And finally, a group of geoservices that will supply pilots and users with specific functions (not query functions) that allow them to get specific information and geodata. An example of this function is the geoservices supported on GeoRSS. Until now, we have developed the first two schemes; the third one is still being modelling. But we have also implemented some concept testing that allows us to be sure about the viability and feasibility of these services. These three components are described in detail below on 6.

As far as here we have described the theoretical concepts and the elements we take into account to create a comprehensive and useful aeronautical server. From now, we will describe the project and its elements.

Table 1 Description of OGC Geoservices.

Service	Definition
Geocoding	
Catalog Web Service (CWS)	Supports the ability to publish and search collections of descriptive information (metadata) about geospatial data, services and related resources.
Gazetteer Service (WFS-G)	Gazetteer services are considered as a specialisation or application profile of the Web Feature Server (WFS-G).This service support the ability to search and find geographic phenomena by their name.
Filter Encoding Standard (FES)	Defines an XML encoding for filter expressions. A filter expression combines constraints on the properties of a feature in order to identify a particular subset of features to be operated upon using geometric, spatial, logic and arithmetic restrictions.
Accessing	
Web Feature Service (WFS)	Allows a client to access, query, retrieve and manage vector geospatial data encoded in Geography Markup Language (GML) from multiple and remote heterogeneous sources.
Web Coverage Service (WCS)	Defines a standard interface and operations that enables interoperable access to geospatial "coverages" such as satellite images, digital aerial photos, digital elevation data.
Geographic MarkUp Language (GML) KeyHole MarkUp language (KML)	These Mark-up languages permits encode geospatial information and its attributes.
Geospatial Digital Rights Management Reference Model (GeoDRM)	Defines a conceptual model for digital rights management of geospatial resources.
Rendering	
Web Map Service (WMS)	Provides an interface for requesting map images from one or more distributed geospatial databases in order to be displayed in a browser application.
Web Terrain Service (WTS) Web Perspective Service (WPVS)	Enables services for visualization of geographic features using perspectives and 3D models.
Symbology Encoding (SE)	Defines an XML language for styling information used to portray Feature and Coverage data.
Style Layer Descriptor Profile (SLD)	This profile defines how the Symbology Encoding specification can be used with WMS.
Geoprocessing	
Web Coordinate Transformation Service (WCTS)	Provides a standard way to specify and access coordinate transformation services for use on specified spatial data.
Web Processing Service (WPS)	Provides rules for standardizing how to publish, describe and use geospatial processing services.
Communications	
Sensor Alert Service (SAS)	Permits to subscribe alert services related to data captured by sensors.
Geographically Encoded Objects for RSS feeds (GeoRSS)	Proposal for geo-enabling, or tagging, "really simple syndication" (RSS) feeds with location information.

Definitions based on the OpenGIS® Standards and Specifications. [21]

5. AERONAUTICAL METADATA PROFILE

As we said above, a safety and secure navigation process requires a quite good aeronautical cartography which can guide pilots while they are flying. Until now the most common way to get this information was through paper maps, but media and technology forced to evolve this concept. So, digital information is arising as a new way for supporting flights. One of the main elements so that the digital information is able to be discovered, distributed and query-able is the metadata that describe this information. Actually, metadata are the first element we need to have available. Without metadata it is not possible to think about geoservices and other applications related to geoinformation. That's why we decided to develop a comprehensive aeronautical metadata profile which let us to describe aeronautical data and geoinformation. The most components of the proposed services will be supported by metadata and the services around them. This section describes in brief the aeronautical metadata profile we have developed, proposed and implemented [27].

The big problem stands on the very own characteristics of aeronautical geoinformation which contains details and elements which are not included or contemplated by a common metadata standard. In this way, the current metadata standards which were created to describe conventional geographic information do not apply for describing aeronautical geoinformation and data. These standards do not included explicit fields that are required for describing specific elements of the aeronautical cartography. On the other hand, the current aeronautical International Standards and Recommended Practices, such as the ones published by ICAO [12] (International Civil Aviation Organization) and Eurocontrol [5] (European Organisation for the Safety of Air Navigation), do not describe deeply the elements and metadata that aeronautical charts should take into account. This can lead to different interpretations of the standards by different institutions, bringing to a stop the natural evolution of a common spatial data system for sharing aeronautical geoinformation.

Hence, we have drafted a document which allows standardization of metadata [27]. This draft has been tested using the aeronautical information of the Aeronautical Information Division of Aena (Spanish Airports and Aerial Navigation). This requires establishing a minimum number of elements (fields) so as to describe aeronautical geoinformation correctly and to conduct a study about the feasibility of this geoinformation and its compatibility with other existing regulations. Thus, we established a metadata profile tailored to the needs of Aena and aeronautical information in general.

In order to draw up the aeronautical profile, international metadata standards ([13], [14], [23]) and European ones ([6], [20]) have been taken into account. In addition, due to the fact that Aena plans to become a node of the Spanish Spatial Data Infrastructure [16], the Spanish metadata core ([17]) has been also considered. So as to set focus on the aeronautical component of the data, the study was extended to different specific metadata profiles used in other countries to define their aeronautical information. In each case, the profile's elements were analyzed as well as a sample of instances already created and implemented, in such cases where information was available ([1], [9], [18], [31], [32]). Finally, international standards relating to aeronautical information ([6], [23]) were analyzed in order not to contravene any existing law and to reaffirm the conclusions drawn by our team.

Once we have established the minimum set of metadata elements for describing the aeronautical products, we proceeded to adapt the definition of each element so that both the examples and the guidelines for its implementation were tailored to the needs of Aeronautical Information Services. This way, the drafted document will guide and help to create homogeneous metadata following these guidelines.

For the time being, the results are satisfying. The profile has provided a starting point to create metadata for the whole products of the AIS, has reduced the time that people who is in charge of aeronautical information should spend in studying the standards due to they can find in a single document the most important standards relating to metadata and some common examples which they can use as a point of reference. Finally, it facilitates the development of the activity through a comprehensive document while at the same time supporting the work of the cataloguer. And last but not least, the profile is the first step to assure the interoperability of aeronautical data. Up to now, Aena has catalogued about 25% of their aeronautical data. This information can be requested and queried through [28].

6. AERONAUTICAL SERVER

Now that we are provided with metadata and aeronautical information, we are ready to start the process. The aeronautical data server is comprised by three main services as described above. These services are supported on a platform which has been designed keeping in mind next characteristics: well-supported open source software packages and comprehensive geographic data transmission technology; designing and system architecture is ready to support different platforms and wireless devices; our server is in accordance with OGC, EUROCONTROL and ICAO standards and recommendations. This last characteristic is very important because Spatial Data Infrastructures and related geographic technologies need not only metadata, data sets, spatial services and interoperable technologies, but also agreements to share information, and to coordinate and monitor the processes and this is possible just through standards.

Keeping in mind that: (i) there is a dataset which follows the AIXM model; (ii) these data are stored in a Oracle Enterprise Geodatabase (ESRI); (iii) the data are distributed in a remote server; and (iv) the architecture provides a single central location to access and manage spatial data; we will describe our server.

First of all, in order to set up a private data server which will permit to Aena's members access and query the aeronautical data we have use a privative software called ArcSDE (Spatial Data Engine) from ESRI. ArcSDE is a core component of ESRI's server technoloy. It manages spatial data in a relational database management system such as Oracle and enables it to be accessed by spatial information clients. Spatial Data Engines is a technology that provides the framework to support long transactions. There is a wide range of spatial data engines such as the one mentioned, Oracle Spatial SDO (Spatial Data Object), PostGIS for PostgreSQL or MySQL Spatial Support. The only reason we set up this service using ArcSDE is because Aena is provided with a full package of ESRI's products. Our server application platform supports any spatial extensions following the OpenGIS® Simple Features specifications for SQL described in [22]. This way we can assure that any institution that has the grants to access the data can be connected through this method. Apart from this, the main goal of this implementation is allowing to Aena querying the information using web browser avoiding the necessity of other kind of software.

Secondly, the server offers a set of tools and services which will become accessible and query-able specific aeronautical data layers such as VFR, RNAV and IAC. For this kind of

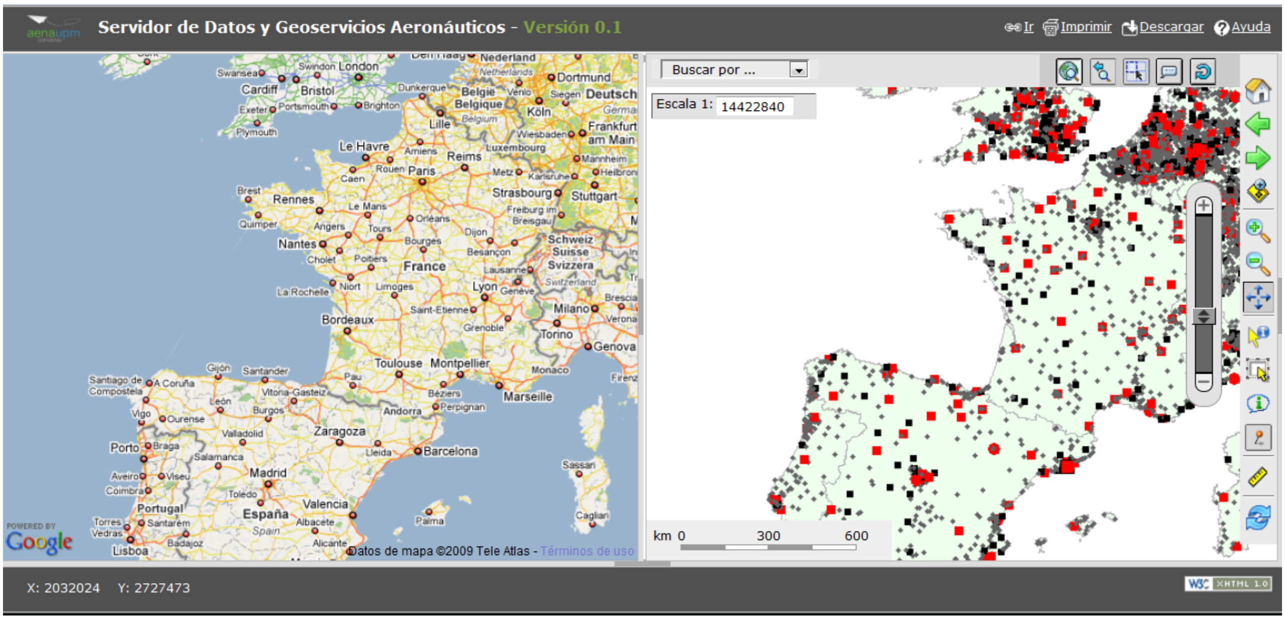

Fig. 4 View of the aeronautical data server showing geographic and aeronautical data

services we have used map server technologies to display this aeronautical data geoinformation over the Internet. As Internet server, we have implemented Apache and as map server, we have selected MapServer, an open source platform for publishing spatial data and interactive mapping applications to the web. These characteristics let us to set up functions and controls for handling geoinformation. The server has different kind of tools and views in order to show on the display different information on different scenarios. It is possible to combine geographic information with aeronautical information as shows in Fig. 4. On this view, pilots can see at all time an aeronautical space reference and information above ground. This function results very useful for VFR.

We have developed five different views for showing different information levels. Each one is thought for different phases of flight. The first one shows a single panel in which aeronautical geoinformation is rendered; through this view, pilots could access and query information and aeronautical charts by hand. Next module is named *upmGMap*, through this one we use the Google Maps API to show the whole geographic information stored in Google Maps servers; the function splits the display in two different panels to show both geographic (left view) and aeronautical (right view) information; the two panels are perfectly synchronized showing at the same time same information using the same system reference (WGS84).

The third one also uses split-panels but unlike *upmGMap* shows aeronautical data in both of them. This module is called *upmDetail*. Through this module pilots can watch simultaneously aeronautical charts and information of different phases of flight. For instance, they could check on the left panel Area Charts while they are watching Visual Approach Chart in the right one. The idea is show information from different scale at the same time, pilots can decide which scale they need and system will show the information according to the selected scale. This way, we are providing pilots with information to facilitate the transition of different phases.

The fourth module is named *upmClone*. This one is very similar to *upmDetail*. Two different panels, both of them display aeronautical information. The difference is that pilot has controls and functions in both displays and he can interact with the system through independent interfaces. Each panel is completely independent from the other. The pilot can select which information is available on each view.

There is also available a module called *upmProfile*. Although this module is still under development, pilots will be able to have a profile view when they were using Instrument Approach Charts, Visual Approach Charts or Aerodrome Obstacle Charts. So, pilots could watch at the same time a side view and top view improving the security process. Finally, there is a module called *upmReset* which restores the display navigation manager to the original view.

Complementary to these tools, there is a draft module which uses XML messages. We are trying to send digital NOTAM using GeoRSS services. We propose to create a central NOTAM server in which aeronautical institutions update information and aeronautical information users can access it just syndicating GeoRSS feeds. In order that this service can be accessed for anyone and compatible with other platforms, this service will be based on the OGC recommendation GeoRSS GML. It must be highlighted that this service is currently just a draft. All these group of functions and services can be accessed in trial mode in [30].

Thirdly and finally, there are a group of geoservices that will supply users with specific functions (not query functions) that allow them to get specific information and geodata. For these functions we are keeping in mind the OGC standards and recommendations mentioned above. This phase of the project is being designed and the services will be available by the end of the year. So, no technical details about these services will be given on this article.

In brief, the data and geoservices that aeronautical institutions could offer through our proposal can be classified in two types. On the on hand there is set of tools for pilots and on the other hand we have setup and programming some services in order to share data and aeronautical geoinformation at different levels: private or public. It will finally depend on restrictions or availability of information and legal issues of the institutions or countries how this information is shared and published. It is completely possible to think about a unique spatial aeronautical data infrastructure which unifies aeronautical information and services in a single but not centralized system. This also means democratization of information. Everything supported by comprehensive technology and strong standards.

7. CONCLUSION

Some recent technological developments allow us to propose this aeronautical information architecture. Elements associated with computer technologies, the availability of electronic aeronautical information, the strong standards related to aeronautical information and geographic services, and the increased implementation of navigation systems with high positional accuracies, have created an environment well suited to the development of viable systems which support electronic charts for display in the cockpit, Web and mobile devices.

An electronic aeronautical chart display has the potential for functionality that exceeds beyond all expectations paper charts and could offer significant benefits and improvements such as customization of the chart display depending on the phase of flight and other operational considerations. The five different views and services described on this paper are clearly a strong support for flight and share aeronautical information.

Aena has tested and validated these services and the results we have achieved. The services are not available for professional and commercial because it takes a long time. Despite this, the test process indicates we are in the right direction in order to provide new technologies and methodologies that help at standardizing electronic aeronautical chart displays. Everything based on a new cartographic technology.

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